DE 19,605,226 A1

Job No.: 5000-81175
Translated from German by the Ralph McElroy Translation Company
910 West Ave., Austin, Texas USA 78701

FEDERAL REPUBLIC OF GERMANY
PATENT OFFICE
PATENT NO. 196 05 226 A1
(Offenlegungsschrift)

Int. Cl.[6]:	H 05 H	1/48
	H 01 J	17/49
	B 01 D	53/86
	B 01 J	19/08
	G 09 F	9/313
	//B 08 B	7/00

Filing No.: 196 05 226.2

Filing Date: February 13, 1996

Date Laid Open to Public Inspection: August 14, 1997

METHOD FOR FORMING A PLASMA AS WELL AS USE FOR A PLASMA FORMED IN THIS WAY

Inventors:

Dr. Karl-Heinz Gericke
38012 Braunschweig, DE

Dr. Anselm Tobias Haas
60431, Frankfurt, DE

Dr. Michael Lock
60327 Frankfurt, DE

Dr. Volker Dangendorf
38176 Braunschweig, DE

Dr. Horst Schmidt-Böcking
65779 Kelkheim, DE

Angela Demian
65830 Kriftel, DE

Applicant:

Dr. Karl-Heinz Gericke
38102 Braunschweig, DE

Dr. Horst Schmidt-Böcking
65779 Kelkheim, DE

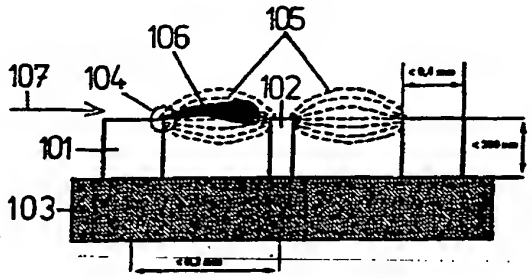
Agent: Patent Attorneys Viël & Viël
66119 Saarbrücken

References Cited: DE 36 05 735 A1
Patent Abstracts of Japan for:
JP 07142192A

Examination request according to §44, Patent Act has been filed

The following information has been taken [unedited] from documents submitted by the applicant

The present invention pertains to a method for forming a plasma, in which the plasma is created by means of free electrons interacting with other particles. The plasma is created as a plasma surface, in which free electrons with such an electric field strength are created, whereby the plasma surface is produced by means of cold emission from a solid, in particular, metal, without special ambient conditions, such as high temperature. The electric field strength originating the emission is designed locally limited by the geometry of the electrode structure, in particular, for electrode structures of a few nm to mm, and there are many locally limited electric fields next to each other essentially in one plane.



The present invention pertains to a plasma according to the preamble of Claim 1, as well as the use of such a plasma according to Claims 5-10.

Such a method is already known to the applicant, in which free electrons at a sufficient energy interact with other particles like molecules, atoms, solids, ions, or radicals, and in this way, create the plasma.

By the method according to Claim 1, a plasma can be formed in a simple way, and its formation does not place any special requirements on the ambient conditions. Due to the

sufficiently large eiectric field strength, the plasma can be formed, in particular with ambient conditions like normal air pressure and room temperature. In this way, an additional advantage compared with other known methods for forming a plasma consists in that a large plasma surface results without requiring the creation of a large volume plasma.

For such a large volume plasma, by means of which conventionally up to now, a plasma with a comparatively large surface was created, at most only the edge region can be used in industrial applications.

These known application methods are, e.g., cleaning, etching, and vapor deposition of surfaces, cutting of materials, light generation in lamps, plasma display screens, applications in gas phase chemistry in the general sense and the like.

Thus, a large plasma edge surface is essential for these applications. In the known state of the art, this leads to a comparatively large volume plasma, in which there can be correspondingly high temperatures in the interior, which can then lead further to undesired reactions.

Furthermore, for the creation of plasma according to the state of the art, exactly defined conditions relative to pressure and temperature are necessary. Furthermore, in practice, a large volume plasma excludes quick adaptability, e.g., relative to ion density and ion transport. In any case, this is not possible with short time constants and exact positional resolution.

In contrast, with the method according to Claim 1, a plasma can be formed that is exactly defined relative to its spatial extent and relative to the components contained in it, as well as its temperature distribution. Thus, this plasma surface can have sufficient extent for a plurality of applications simultaneously. In particular, for such a plasma, the relation of the plasma surface to the plasma volume can be chosen arbitrarily, i.e., also arbitrarily large. By the method according to Claim 1, locally limited plasmas can be integrated into a large plasma surface.

Through the possibility of a small and simultaneously controllable plasma extent in a certain direction, a plasma can be supplied arbitrarily dense to objects that are to be processed or modified by means of this plasma.

Through the method according to Claim 2, the entire plasma can be adapted for different applications. In this way, the individual plasma surfaces can be different relative to their composition and temperature distribution. For example, if a gas passes through these plasma surfaces, this gas can be processed by different plasmas in series.

With the method according to Claim 3, the plasma can be adjusted by means of the electric field strength with both chronological and positional accuracy. Thus, for example, the result, e.g., the rate of a certain chemical conversion of output material, can be monitored as the measurement value. This measurement value can be compared with a reference value. For a deviation, the electric field strength is adjusted so that the measurement value approaches the reference value. Advantageously, this shows that this adjustment is possible with a very short

time constant. In this way, the electric field strength can be varied on the order of magnitude of nanoseconds.

With the method according to Claim 4, a locally different formation of the plasma can be achieved in the targeted plasma surface.

Claims 5-10 show advantageous applications of a defined plasma. The use according to Claim 9 produces spectral adaptability through the use of a certain gas.

An embodiment of the invention is represented in the drawings. Shown are:

Figure 1, an apparatus for creating a plasma,

Figure 2, a side view in cross section of an additional apparatus for creating a plasma,

Figure 3, plan view of the apparatus according Figure 2,

Figure 4, an apparatus for producing a three-dimensional plasma, and

Figure 5, another representation of the apparatus according to Figure 4.

Figure 1 shows a side view of an apparatus that can create a plasma according to the invention. Thus, electrodes 101 and 102 stand opposite each other on a surface 103.

These electrodes are advantageously produced by microstructure technology or nanostructure technology. Alternatively to this production of an apparatus, is it also conceivable to correspondingly coat a plastic film, e.g., with an aluminum foil. In this way, only low resolution can be achieved relative to electrode spacing. However, such a production method is suitable, in particular for applications in mass production, due to its low costs. For production methods in microstructure technology or nanostructure technology, the electrode spacing is set depending on the wavelength of the radiation with which this structure is created. If this structure is created, e.g., with light in the visible range, then this results in an electrode spacing on the order of magnitude of the wavelengths of visible light, i.e., of a few 100 nm. By using radiation of small wavelengths, correspondingly small electrode spacings and thus, correspondingly larger field strengths can be achieved with smaller electrical voltages.

Advantageously, these electrodes 101 and 102 feature a sharp edge 104 on their top side. By applying a voltage between the electrodes 101 and 102, an electric field 105 results between these electrodes. Due to the sharp edge 104, a particularly strong electric field 105 of approximately atomic orders of magnitude results on the top side of electrodes 101, 102, which facilitates the emission of electrons 106 from electrode 101. In this way, a negative voltage is applied to electrode 101 relative to electrode 102.

These electrodes 101, 102 are made out of materials like glass or plastic film by means of already known technology, e.g., lithographic methods. The spacing of the electrodes 101 and 102 is set depending on the production method, and this spacing has an essential effect on the electric field strength.

Through the rectangular, etchable electrode structures, i.e., the sharp edges 104 on the top sides of electrodes 101 and 102, field strengths of such an order of magnitude can also be achieved at comparatively small voltages, so that electrons 106 are emitted. Thus, it is also possible to maintain cold emission of electrons 106 from the cold electrode 101 of electrode 101 designed as a solid-body electrode.

For creating the field strengths, the electrodes 101 and 102 are switched, like in known microelectronics, with direct or alternating voltages on the order of magnitude of a few 100 V. By means of voltages on this order of magnitude, the electric field 105 can then be varied on the order of magnitude of ns. In this way, a control or adjustment of the plasma is possible with a quickly variable correcting value. Altogether, a control or adjustment results with a very short time constant.

Electrons 106 are then accelerated as free electrons in the strong electric fields 105 and create ions or radicals through impact ionization with the surrounding atoms or molecules of the surrounding gas atmosphere. The resulting micro-plasma between the electrodes 101 and 102 can be turned on and off quickly through corresponding switching, i.e., charging of the electrodes 101 and 102 with electrical voltage.

Thus, under these conditions, a plasma can be produced under standard ambient conditions, i.e., normal pressure, room temperature, and without pre-ionization. Simultaneously, the plasma exhibits a small extent perpendicular to the electric field lines, so that ions can be extracted easily by pulsed electric fields and deposited on other neighboring surfaces.

By the application of a plasma created with the apparatus, e.g., a gas can flow over the surface in the direction of arrow 107 and thus, interact with the plasma formed, in particular, on the top side of electrodes 101 and 102. Likewise, it is also conceivable to initiate this surface correspondingly dense at the top side of a solid to be processed by the plasma. Another flow direction of gas can be formed essentially perpendicular to the plane of the paper.

Figure 2 shows an additional configuration of a cathode 101 and an accompanying anode 102, by means of which a plasma can be created. Anode 102 and cathode 101 can be attached to a plastic film 103. The electric field 105 is formed again by the application of an electrical voltage between the electrodes 101 and 102. Through a corresponding production method, the electrodes 101 and 102 again feature a sharp edge 104 at the top side. If the plastic film 103 acting as a support features holes 202, the gas can flow in the direction of arrow 201 when there is a sufficiently large number of holes 202. The gas then passes through the plasma surface perpendicularly. Figure 2 shows a side view of the apparatus in cross section, in which the holes 202 can be seen directly.

The representation according to Figure 3 shows a plan view of the apparatus according to Figure 2. The cathode 101 is again labeled with the reference number 101. The plastic film 103

is perforated by holes 202. These holes 202 lead to a honeycomb structure of the plastic film 103, so that there is mechanical connection of the electrodes behind as well as forward, and yet, the gas can flow perpendicularly through the plasma surface.

With the apparatuses described up until now, the gas can only interact with a plasma surface. Through a corresponding switching of the individual electrodes at the surface, the plasma can also be formed differently within the surface.

However, it is also possible, to let the gas flow perpendicularly through the plasma surface and in this way, there can be several of these plasma surfaces in series in the flow direction of the gas.

An advancement for producing such a plasma that is adjustable and/or controllable in three-dimensions is given by so-called LIGA technology. By means of this technology, it is possible to produce a corresponding electrode structure in three dimensions. (LIGA = Lithography, electroplating, molding, described, e.g., in W. Ehrfeld, H. Lehr: Radiation, Physics ND Chemistry 45 (3), 349-365 (1995)). If an electrode structure is created by this method so that electrodes are sufficiently dense and formed with corresponding sharp edges, then plasma fields corresponding to three dimensions can be created.

An example of this is given by the representation according to Figures 4 and 5.

Figure 4 shows a side view of an arrangement of electrodes 101 and 102 that again feature correspondingly sharp edges 104 at the corners. These electrodes are held by support walls (e.g., made out of plastic) at a defined spacing. Thus, the electric field 105 is produced again between the electrodes. By means of corresponding holes, the gas flows in the direction of arrow 401. Thus, the gas flows through several plasma surfaces.

Figure 5 shows a plan view of the apparatus according to Figure 4. The electrodes 101 and 102 are again held by a support made out of plastic 103, which, however, must feature holes 202 again so that the gas can flow through the plasma surfaces.

The production is done such that, e.g., there are metallic electrodes in a massive plastic block. By means of LIGA technology, the corresponding structure is then formed with sharp edges for the electrodes.

A possible application of such created plasmas is, e.g., for gas phase chemistry. The electrons in the plasma feature a large energy and thus, they are in a position to break just about any electric bond. The kinetic energy of the electrons is comparatively precisely adjustable, so that the energy for the stimulation of certain reactions can be adjusted. Thus, the energy of the electrons can be varied over an energy range of a few 10 eV. In this way, the primary electron acts like a dynamically induced catalyst that is still unconsumed after the reaction and is available for additional reactions. Although the electron gas is extremely hot and can thus break any chemical bond, the gas atoms or molecules remain at practically the ambient temperature of

the reactor container. Thus, chemical reaction zones can be produced by the plasma, and these zones have two separated, selectable temperatures for reaction stage 1 (e.g., dissociation of initial molecules) and for reaction stage 2 (synthesis of end products).

Thus, the plasmas allow a completely new type of gas phase chemistry. For environmental protection, e.g., dioxins and nitrogen oxide can be reduced by cold combustion induced by electron impacts. Large amounts of nitrogen oxide can also be separated into nitrogen and oxygen.

In addition, materials can be cold-synthesized that up until now could only be converted at very high temperatures with comparatively complicated means. In this way, for example, it is possible to convert methane into acetylene, ethylene, and ethane. Likewise, a conversion of ethane into acetylene can be considered.

Additional conceivable possible applications are to be represented briefly in the following. For example, noble gas ions or excited noble gas atoms in a noble gas atmosphere can be created in a very thin layer directly on the surface to be processed. The created noble gas ions can etch every contaminant on the surface or parts of the surface due to its high ionization energy and, after the etching reaction, they are available again in a completely environmentally friendly way as neutral noble gas atoms for subsequent reactions. Due to the good controllability and adjustability of the plasma, the surface processing can be done locally and very accurately.

Likewise, surfaces can also be vapor deposited. Due to the good controllability of the plasma, application for printing and writing systems is conceivable, because the plasma can also be created directly under standard thermodynamic conditions.

Claims

1. Method for forming a plasma, in which the plasma is created by means of free electrons interacting with other particles, characterized in that the plasma is created as a cold plasma surface, in which free electrons with such an electric field strength are created, so that the plasma is produced by means of cold emission from a solid, in particular metal, without special ambient conditions, like high temperature, and in that the electric field strength originating the emission is designed to be locally limited by the geometry of the electrode structure, in particular for electrode structures of a few nm to mm, and in that there are many locally limited electric fields next to each other essentially in one plane.

2. Method according to Claim 1, characterized in that several plasma surfaces are created in at least one direction formed essentially perpendicular to the plane.

3. Method according to one of Claims 1 or 2, characterized in that the plasma is controllable or adjustable under the use of electric field strength as correcting variable.

4. Method according to one of Claims 1-3, characterized in that the plasma can be adjusted locally by means of a locally adjustable electric field strength.

5. Use of a plasma formed according to one of the previous claims for use in a catalytic converter for exhaust gas purification.

6. Use of a plasma formed according to one of Claims 1-4 for synthesis of complex chemical bonds from simple basic components, e.g., for creating large amounts of hydrocarbons out of methane.

7. Use of a plasma formed according to one of Claims 1-4 for cleaning and/or etching surfaces.

8. Use of a plasma formed according to one of Claims 1-4 for vapor depositing and/or coating surfaces.

9. Use of a plasma formed according to one of Claims 1-4 as a large area spectral light source and/or spectral lamp.

10. Use of a plasma formed according to one of Claims 1-4 as a flat display screen.

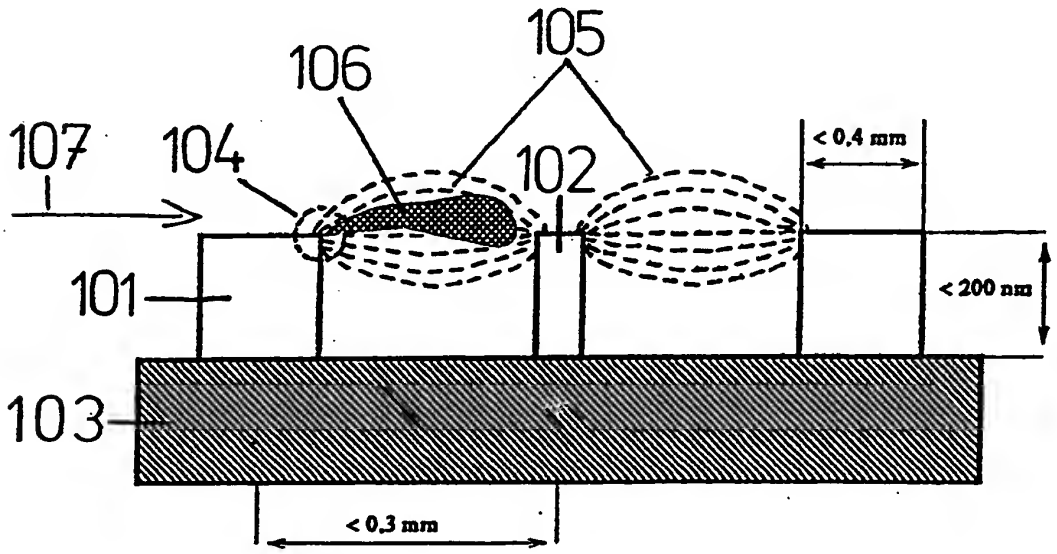


FIG. 1

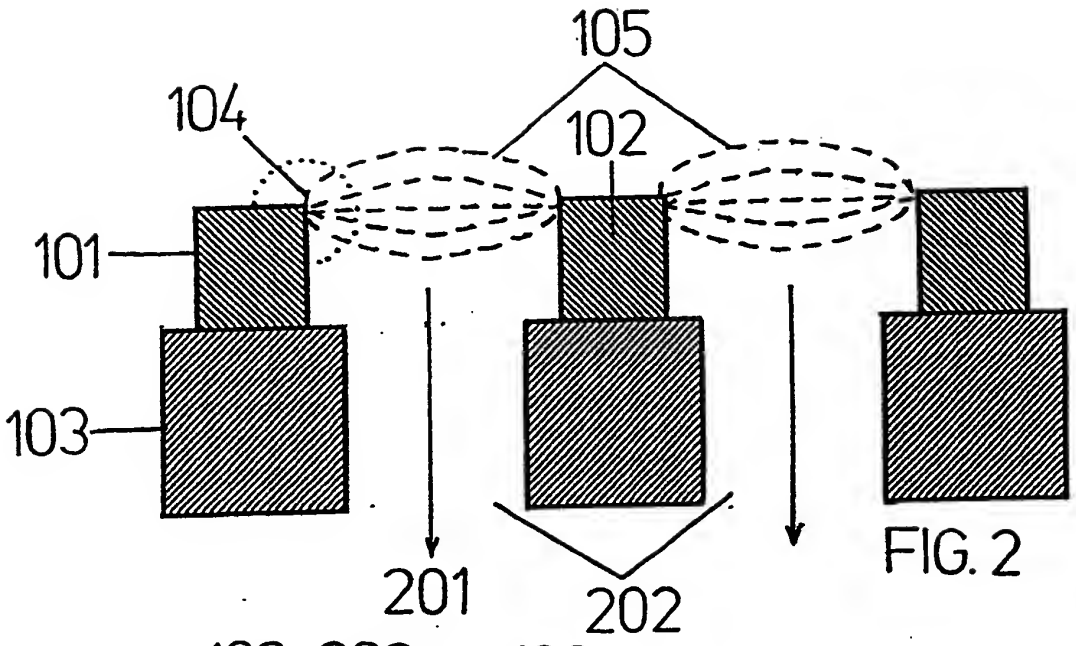


FIG. 2

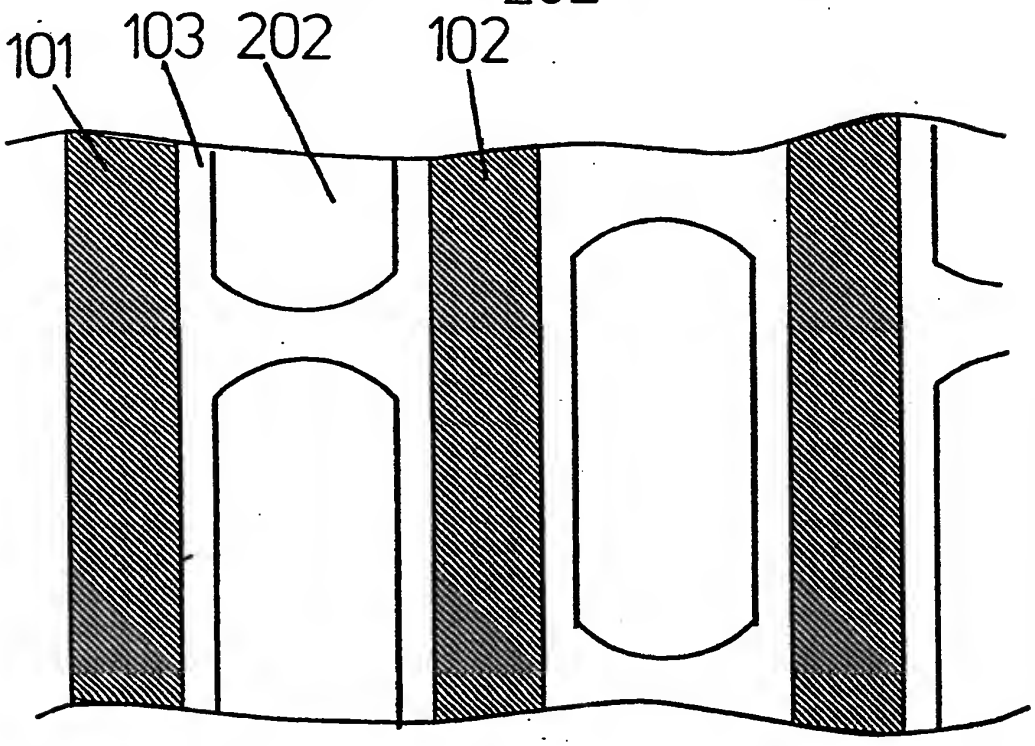


FIG. 3